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DIVISION Power Systems
TM 7996:70-629
DATE 17 July 1970
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TECHNICAL MEMORANDUM

AUTHOR(S): E. S. Chalpin

TITLE: Design Review of PCS-G Condenser, P/N 1268340-1,
Redesigned from P/N 093043

ABSTRACT

A limited redesign of the condenser has been undertaken. The purpose of this redesign was to modify two existing condensers so that they would more closely comply with redefined requirements of the SNAP-8 system, and could be used in the Power Conversion System (PCS-G) for the Combined System Test (CST).

The NaK and mercury inlet and outlet ports were redesigned for higher allowable interface loads. The NaK side of the condenser was redesigned for a lower pressure drop. A modification of the mercury inlet was made to obviate the need for a bellows as well as to incorporate an evacuation port for removing noncondensable gases from the Rankine loop. The existing design was also modified to incorporate the new method of attachment to the PCS.

This design review is a presentation of the above changes that will be applied to two existing condensers.

KEY WORDS: Condenser, redesign, SNAP-8 Power Conversion System

APPROVED:

DEPARTMENT HEAD

R. W. Marshall, Jr.
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NOTE: The information in this document is subject to revision as analysis progresses and additional data are acquired.



AEROJET-GENERAL CORPORATION

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I. INTRODUCTION

There are currently two (2) condensers, P/N 093043, B/U 3/1 and 4/1, available for the SNAP-8 Power Conversion System (PCS). However, changes in the PCS design dictated that these condensers required the following modifications to make them acceptable:

A. NaK and Mercury inlet and outlet ports needed redesign for higher interface loads.

B. NaK side redesign for a lower pressure drop.

C. Mercury inlet redesign to obviate the need for a turbine assembly-to-condenser bellows as well as to incorporate an evacuation port for removing noncondensibles.

D. A new method of attachment between the condenser and the PCS.

This report covers the design effort to accomplish the foregoing modifications.

II. DISCUSSION

A. HISTORY AND STATUS OF CONDENSERS

There were four (4) condensers built for the SNAP-8 program. Each one's history and current status is as follows:

1. P/N 093043-1 "B", S/N A-3, B/U 1/2, Log No. 1108, tube bundle P/N 092553-1. The condenser shell was fabricated from type 410 stainless steel and the mercury containment tapered tubes (73) were fabricated from 9% chrome, 1% molybdenum (9M) steel. The tapered tubes were welded and back-brazed to the headers.

This unit had operated for 756 hours in the SL-1 test facility prior to being environmentally tested per NASA Specification 417-2 at the NASA-LeRC Test Laboratory. The unit completed all tests (vibration and shock) with no deleterious effects (see TM 7996:70-624, dated 21 April 1970). This condenser is currently being held in stores as a spare for the PCS-1 unit.

2. P/N 092500-1 "C", VEO #2393, S/N A-2, B/U 2/2, Log No. 1034, tube bundle P/N 092553-1. As above, the condenser shell was fabricated from

type 410 stainless steel and the mercury containment tapered tubes were welded and back-brazed to the headers.

This unit has been operating for 13522 hours in the PCS-1 test facility through 31 March 1970. It is planned to continue operation during the remainder of the PCS-1 test program.

3. P/N 093043-3 "F", VEO #0547, S/N A-1, B/U 3/1, Log No. 1080, tube bundle P/N 092553-3. The condenser shell is type 410 stainless steel and the tapered tubes (73) are 9M steel. The tapered tubes were rolled and welded to the headers with no back-brazing.

This unit has never been operated in any test facility and is currently in stores. It is one of the two condensers that will be modified to the configuration described herein.

4. P/N 093043-5, S/N A-1, B/U 4/1, Log No. 1035, tube bundle P/N 094620-1. The condenser shell is type 410 stainless steel and the tapered tubes (73) are 9M steel. The tapered tubes were rolled and welded to the headers with no back-brazing.

This unit has operated in the NASA-LeRC W-1 test facility for 2568 hours and 135 starts. It is currently in the W-1 test facility which has been "mothballed." This condenser is the second unit that will be modified to the configuration described herein.

B. REDESIGN REQUIREMENTS AND GROUND RULES

The redesign of the condenser was based on the AGC Specification 10625, Part I, dated 10 December 1968, "Condenser, Mercury, Prototype" with particular emphasis on the following:

1. Paragraph 3.2.1 of AGC Specification 10625

The inlet and outlet service fluid (NaK and Mercury) connections shall be capable of withstanding any combination of radial and axial forces and bending and torsional moments at the maximum operating temperatures (910°F) and pressures (110 psia) that the connecting tubing is capable of withstanding. Interface loads shall not cause loss of fluid containment, excessive deformation, or any condition which would prevent the condenser from meeting the operating life (40,000 hours) or performance requirements.

2. Paragraph 3.1.1 of AGC Specification 10625

The NaK side pressure drop shall be 4 ± 2 PSID at 40,000 lb per hour NaK flow.

3. Figure 1 of AGC Specification 10625

The condenser envelope shall be such that the mercury inlet shall be redesigned to obviate the need for a turbine assembly-to-condenser bellows. An evacuation port at the mercury inlet shall be provided to remove noncondensable gases from the mercury loop. Orientation and length of the NaK inlet and outlet ports were coordinated with the PCS-G design group.

4. The method of attachment between the condenser and the PCS was coordinated with the PCS-G design group. The condenser will be held only at the upper flange bolt circle.

The ground rules that were established by the SNAP-8 program for the condenser are:

a. The two existing condensers, P/N 093043, B/U 3/1 and 4/1 will be used for the redesign. The tube bundle, headers and NaK shell will not be modified or replaced.

b. The modified condenser will be used at its off-design operating point as called out by the new PCS State Point of 21 April 1970. This operating point was tested with the condenser currently in PCS-1 and the results were reported by J. Hodgson in Memo 7994-70-1229.

c. The two modified condensers will be acceptance tested but will not be tested in a liquid metal system. One will be delivered to the PCS-G and one will be held as a spare.

d. The environmental tests performed on P/N 093043-1 "B", S/N A-3, B/U 1/2 will suffice as adequate proof that the modified condensers will meet the requirements of NASA Specification 417-2. This is a reasonable assumption since the tube bundle and NaK shell are unchanged and the service fluid ports are designed to be stronger than the unit tested.

e. Any redesign of a component shall be based on the original PCS-G state point conditions, if practical, instead of the less severe conditions indicated by the 21 April 1970 state point.

C. DESIGN ANALYSES OF THE CONDENSER MODIFICATIONS

1. NaK Side Pressure Drop Analyses

Appendix A outlines the pressure drop analyses performed by A. J. Sellers. Five cases were studied:

a. The original condenser design which indicated a NaK side pressure drop of 10.62 PSID (Design A).

b. The modification of the original design that is currently operating in PCS-1 and has a calculated pressure drop of 4.20 PSID. The NaK inlet flow deflector was deleted in this modification (Design B).

c. A further modification of Design B to reduce the pressure drop to a calculated 2.83 PSID. The shell exit orifices are increased from 0.625 to 0.750 inches in diameter and the inlet and exit manifolds are increased (Design C).

d. A modification of the tube bundle was added to attain uniform flow distribution in the shell-tubes assembly. This resulted in a calculated pressure drop of 5.38 PSID (Design D). This design included eccentric NaK manifolds and turning vanes in the NaK inlet manifold.

e. A modification of Design D in that the NaK flow orificing around the mercury tubes to attain uniform NaK flow was omitted. The calculated drop was reduced to 3.53 PSID (Design E).

It was concluded that Design C would be recommended with a minimum attainable NaK side pressure drop and minimum rework as the bases for the recommendation. The ground rule that the tube bundle and shell are not to be redesigned dictated the degree to which the NaK side pressure drop could be reduced. Since the pressure drop requirement as stated in AGC Specification 10625 is 4 ± 2 PSID, it can be seen that Design C at 2.83 PSID is acceptable.

2. Detail Design Modifications

Figure 1 "Condenser, PCS-G" is the assembly drawing of the modified unit. The following changes to the original condenser were incorporated:

a. The mercury inlet and outlet were removed. The NaK inlet and outlet were removed. This left the shell and tube bundle intact.

b. The small (0.125 in. dia.) holes at the NaK outlet were repositioned to agree with the low point bleed of the new NaK outlet header. The 0.625 in. diameter NaK exit holes (12) were enlarged to 0.750 in. diameter to decrease the NaK pressure drop.

c. The upper flange bolt holes (6) were increased to 0.404 - 0.411 in. diameter to accommodate the new method of installation of the condenser in the PCS-G as requested by D. Ward of the PCS-G design group.

d. The mercury inlet cone was modified by decreasing the length of the pressure taps and adding the evacuation port. The lengths were shortened so that the condenser installation bracketry could be slipped over the mercury inlet and mate with the flange without interference.

e. The cylinder shown attached to the cone of the mercury inlet replaces the flange and bellows called for on the previous design. The cylinder is made of low alloy steel for resistance to mercury corrosion and to allow welding to the turbine assembly exhaust without post-welding heat treat.

f. The NaK outlet manifold and tube were made of a two-piece forging welded along its girth. Its size was increased to accept the 3-inch diameter heat rejection loop piping required for the PCS-G at the new design point conditions. The manifold assembly can be slid over the smaller end of the tube bundle, moved along to the position shown and welded into place.

g. The NaK outlet manifold and tube assembly is made in the same manner as the outlet manifold, slid into position and welded. The flow splitter shown, is placed into the manifold prior to making the girth weld, its purpose being to decrease pressure drop by more evenly supplying NaK to the 12 NaK inlet orifices.

h. The mercury outlet dome was redesigned for one-piece construction to increase its strength and reduce stresses. The material is type 316 stainless steel to obviate the need for a transition weld from the condenser to the PCS-G piping.

All drawings have been reviewed by production, materials, stress, quality assurance and PCS-G systems personnel.

3. Stress Analyses

All modified condenser parts were analyzed by the Stress Group to evaluate structural integrity at a maximum operating temperature of 910°F and a maximum operating pressure of 110 PSIA. These conditions were chosen in conformance with the ground rule that any redesign of a component should be based on the original PCS-G state point conditions, if practical, instead of the less severe conditions indicated by the 21 April 1970 state point.

The modified condenser design meets all the stress criteria as noted in Appendix B. The stress analysis showed that the mercury inlet cylinder material (mild steel) was acceptable for the application if some yielding is allowed. The requirements that the cylinder be mercury corrosion resistant, that it be capable of high temperature (670°F) operation and that the material be such that it can be welded without stress relief heat treat (so that field stress relief will not be required) were controlling factors.

The effects of the new method of condenser attachment were also analyzed in detail and found to be acceptable.

III. DESIGN REVIEW CHECK LIST

The Design Review Check List, Appendix C, is an integral part of the design review documentation package as required by Power Systems Division Procedure I-A6c. A failure modes and effects analysis was not prepared since this task is nothing more than a rework and modifications of an existing design that has demonstrated excellent reliability.

IV. CLOSING REMARKS

The design modifications to the condenser discussed herein are acceptable to the Systems Analysis Group for use in the PCS-G for the Combined Systems Test. They expect that, based upon the analytical and experimental investigation that are currently underway*, the requirements and expected performance of a zero "g" SNAP-8 condenser will require additional changes such as added mercury tapered tubes. These revised requirements will be incorporated in the next condenser specification revision.

* To be published as "Analytical and Experimental Investigations of SNAP-8 Condenser Operation Extended into the Choked-flow Region", TM 7994:70-631.

The detailed plans for attachment of the condenser to the system piping, the turbine alternator assembly and the frame mounting were coordinated with the personnel responsible for such interfaces.

Fabrication techniques were analyzed to determine the most economical, simplest, and most expeditious methods of manufacturing the modified condenser without jeopardizing the integrity of the condenser shell and tube bundle.

Although the SNAP-8 Program does not include the testing of the modified condensers in a liquid metal operating system, the extent of the modifications do not appear to be sufficient to affect the past successful testing of like units, nor does it appear that the environmental results on a like unit will be any different.

2. REMOVE ALL BURRS AND SHARP EDGES.

3. GUN TUNGSTEN ARC WELD PER AGC-10227/1 USING ITEM A WELD ROD, WELDER QUALIFICATION PER AGC-14067.

4. GAS TUNGSTEN ARC WELD PER AGC-10227/1 USING ITEM A WELD ROD, WELDER QUALIFICATION PER AGC-14067.

5. GAS TUNGSTEN ARC WELD PER AGC-10227/5 USING ITEM B WELD ROD, EXCEPT WHERE OTHERWISE SPECIFIED. WELDER QUALIFICATION PER AGC-14067.

6. RENEWAL INSPECT WELDS PER MIL-T-6066, TYPE II, METHOD B. NO DEFECTS ALLOWED.

7. RADIOGRAPHICALLY INSPECT WELDS PER AGC-STD-1151. INTERPRET PER AGC-15800, TABLE 1, CLASS II.

8. PRIOR TO RADIOGRAPHIC AND PENETRANT INSPECTION, STRESS RELIEVE PER MIL-H-6875 AT 1350°F ± 25°F FOR 10 HOURS. (STRESS RELIEVE MAY BE OBTAINED BY COOLING AT RATE OF 100°F PER HOUR TO 1350°F, HOLDING FOR 1 HOUR, AND COOLING AT RATE OF 100°F PER HOUR DURING STRESS RELIEVE.)

9. RECOMMENDED STRESS RELIEVE PROCEDURE: FROM THE A. SUSPEND THE CONDENSER IN POSITION. FROM THE SUPPORT RING AT THE BIG END, USE A RADIATION SHIELD TO HELP MAINTAIN A MINIMAL TEMPERATURE DIFFERENCE BETWEEN SHELL AND INNER TUBES.

B. PURGE THE RETORT AND NUK 4 M9 SIDES OF CONDENSER WITH ARGON OF 20% DEWPOINT AT 10 CFH PER HOUR DURING STRESS RELIEVE.

C. INCREASE THE RETORT TEMPERATURE TO 1850°F ± 25°F.

D. HOLD AT 1850°F ± 25°F, FOR ONE (1) HOUR.

E. DECREASE RETORT TO ROOM TEMPERATURE.

F. MAINTAINING A TEMPERATURE DIFFERENCE OF 0°F TO 50°F BETWEEN THE SHELL AND THE CENTER TUBE OF THE TUBE BUNDLE.

G. HELIUM LEAK TEST PER MIL-STD-871, NO LEAK SHALL BE DETECTED USING AN INSTRUMENT CAPABLE OF DETECTING LEAKS OF 100 CMH OR LESS OF 10⁻⁵ INCHES. ALL LEAKS SHALL BE IDENTIFIED AND REWORK.

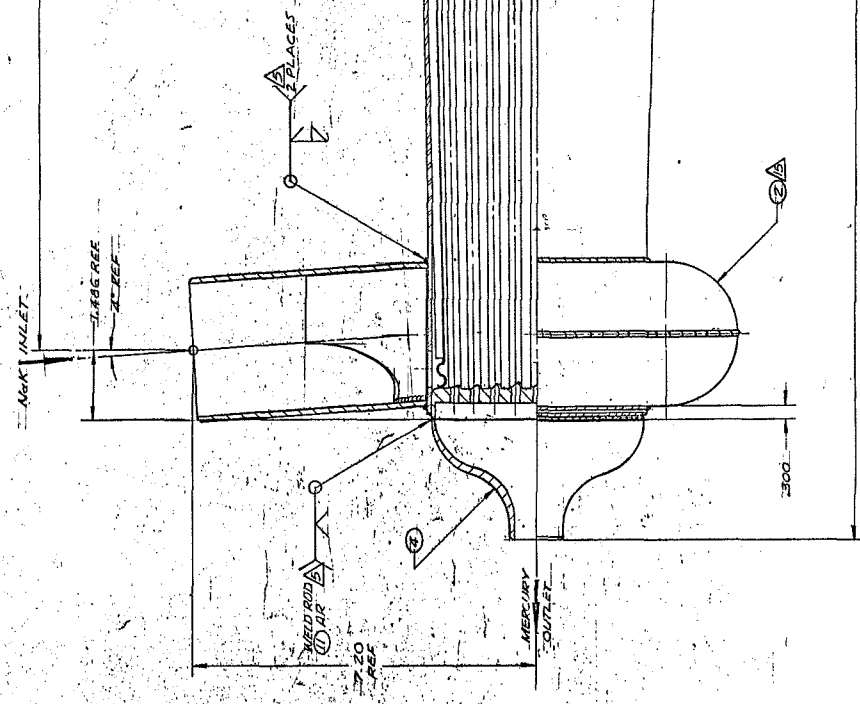
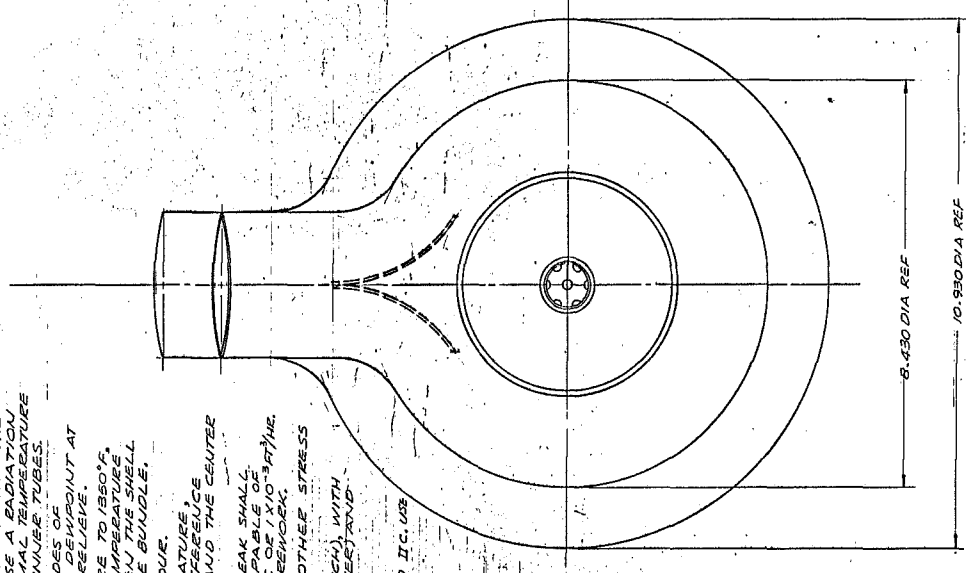
10. 200 MICKS, SCRIBES, TOOL MARKS, OR OTHER STRESS MARKS PERMITTED.

11. MARKS PER AGC 1713 (ELECTROLYTIC ETCH) WITH 100340-1 (APPROPRIATE SECTION LETTER) AND ASSIGNED SERIAL NUMBER.

12. ACCEPTANCE TEST PER AGC-STD-1260.

13. PACKAGING PER MIL-P-116, SUB METHOD II, C USE NO CONTACT PRESERVATION.

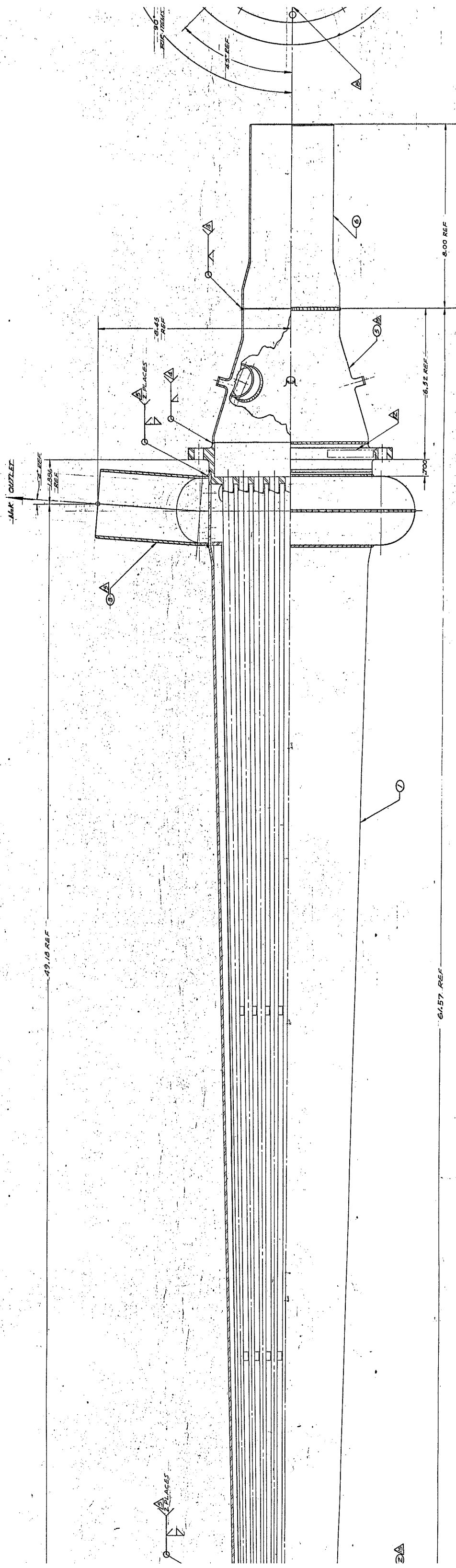
14. TESTS 3 AND 5 MUST BE ASSEMBLED IN RELATION TO THE SCREWS AND X-WITNESS MARKS AS SHOWN.



61.57. REF-

10.930 DIA REF

676
#0069

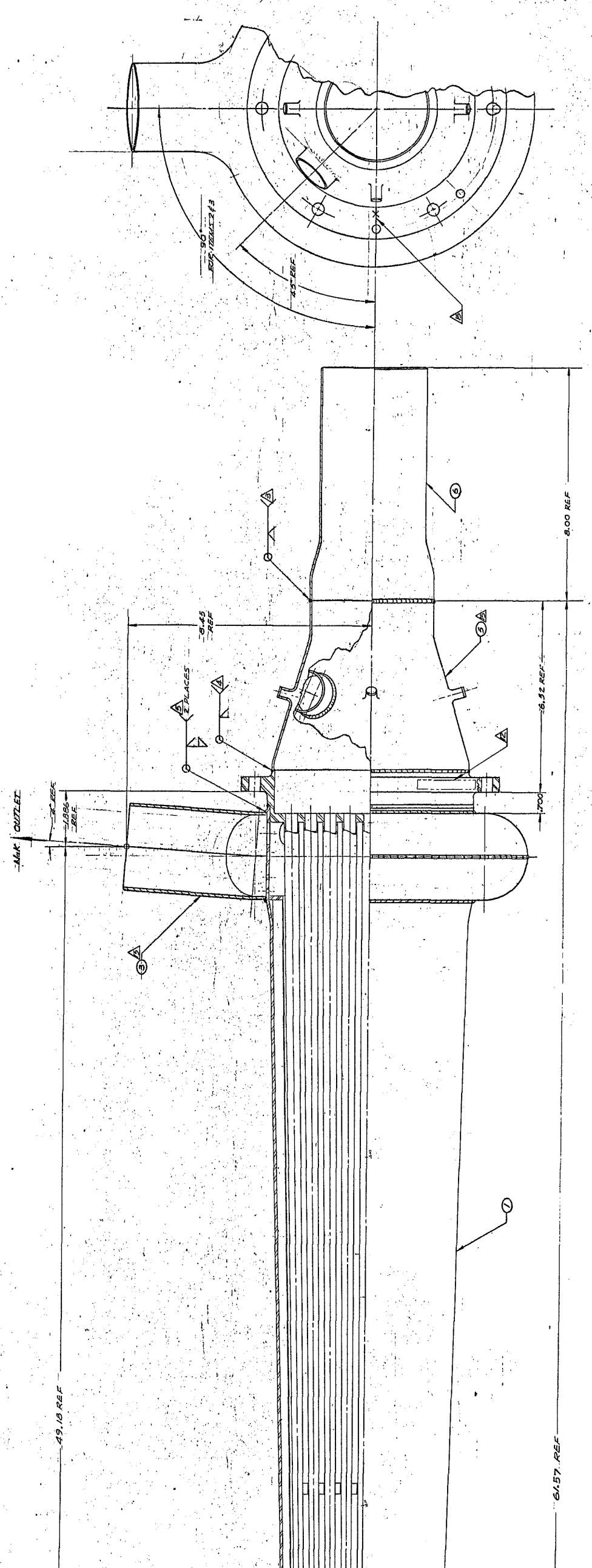


1268340

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FIGURE 1

3

2

APPENDIX A

SNAP-8 PCS-G CONDENSER REDESIGN

DATE: 7 July 1970
7977:70:0001:mrs
Bldg. 160/X4245

MEMORANDUM

TO: E. S. Chalpin

FROM: A. J. Sellers

SUBJECT: SNAP-8 PCS-G Condenser Redesign

COPY TO: T. G. Avila, W. F. Banks, B. Breindel, H. Derow,
C. E. Hawk, A. H. Kreeger, L. P. Lopez, U. A. Pineda

REFERENCE: (a) Memo to E. S. Chalpin from A. J. Sellers,
7973:70:0005, same subject, dated 15 May 1970.
(b) Condenser P/N 092500-5
(c) R. L. Sabiers, "Mercury Condenser Studies", RMR #0074,
15 February 1967, AGC-SACTO
(d) Condenser, Mercury, Prototype, Specification AGC 10625,
Part 1

ENCLOSURES: (1) NaK Shell Side Pressure Drop
(2) Condenser NaK Side Pressure Drop
(3) Schematic-Identification of Pressure Losses
Through Condenser as Tabulated in Enclosure (1)
(4) Hydraulic Analysis of Pressure Losses Through Condenser
P/N 1268340 (Design C)

The SNAP-8 condenser redesign for the PCS-G application involves the modification of the existing Reference (1) condenser in accordance with the following requirements:

1. The NaK inlet and exit headers to be modified for lower NaK side pressure drop.
2. The NaK inlet and exit connections to be modified for higher interface loads.
3. Mercury loop evacuation port to be provided at the mercury inlet end.
4. No conoseal flange connection to be provided at mercury inlet.
5. Mercury inlet port diameter to be modified to meet the TAA exhaust dimension.
6. Relative position of the NaK inlet and exit ports to be flexible in regard to their angular displacement. The final positions will be determined by PCS-G design.

7 July 1970

The reference (1) condenser design was reviewed to ascertain if there is a possibility of reducing the NaK side pressure drop and increasing the interface loading structural reliability. A comprehensive analysis of the NaK side pressure drop distribution and interface loading is provided in Reference (c). The results of the pressure drop distribution in various design configurations are summarized in the Enclosure (1). These design configurations are as follows:

DES. A - is the original SNAP-8 condenser design. Predicted NaK side pressure drop is 10.62 psi. A relatively high local pressure drop of 6.2 psi (57%) results in the deflector area.

DES. B - is the condenser design configuration as provided in the present PCS-1. Because the NaK inlet flow deflector is deleted in this design, the predicted pressure drop results in 4.20 psi. As provided in enclosure (2), the comparative experimental pressure drop is 6.4 psi at $W_N = 47,500$ lb/hr. (the reference PCS-G design NaK flow).

DES. C - is a further modification of DES. B. It shows that NaK side pressure drop can be reduced to 2.83 psi at $W_N = 47,500$ lb/hr. when the shell exit orifice size is increased from .625 to .750 diameter and the NaK inlet and exit manifolds are increased to larger cross section areas.

DES. D - is the modified design configuration attempting to secure uniform NaK flow distribution in the shell-tube assembly. Proposed modifications are: (a) the shell manifolds are to be moved radially 0.40 inch toward the inlet and exit tubes respectively and eccentric to the heat exchanger shell, (b) turning vanes to be added in the inlet manifold, (c) annular orificing (NaK flow metering) to be provided around the Hg tubes at the mercury inlet and exit end about one tube bundle diameter downstream and upstream from the radial NaK inlet and exit ports respectively. Estimated pressure drop for this design is 5.38 psi.

DES. E - is the modified version of the preceding design (DES. D). It omits the NaK flow orificing around the mercury tubes. The estimated pressure drop is therefore lower (3.53 psi).

Both DES. C and DES. E are plausible configurations for PCS-G application when considered in the light of minimum NaK side pressure drop only. Proposed design DES. D offers better heat transfer characteristics because of more uniform NaK velocity and uniform temperature distribution between the mercury tubes. The penalty is, however, the increase in pressure drop (5.4 psi). The predicted NaK side pressure drop of the proposed designs (DES. C, D, E) falls within the present condenser design specifications (4 to 12 psi) as provided in Reference (d). Further pressure drop reduction cannot be attained with the existing mercury tube spacing, which provides relatively high entrance and exit losses (1.6 psi) in the Reference (b) condenser.

Enclosure (2) is a plot of actual NaK side pressure drop versus NaK flow during condenser testing in PCS-1.

Enclosure (3) is a schematic identification of pressure losses through the various condenser designs as tabulated in Enclosure (1).

7 July 1970

Enclosure (4) is the hydraulic analysis from which the tabulation of Design C pressure drops were listed in Enclosure (1). The pressure drops through the tube bundle analyzed in Reference (c) were not re-analyzed since this selection of the condenser was not modified.

In view of the tested condenser (DES. B) heat transfer characteristics as exhibited in the PCS-1 operation, the Reference (b) condenser modifications (redesigns) for PCS-G application is recommended in accordance with the DES. C specifications and layout. Minimum attainable NaK side pressure drop and minimum rework requirements are the bases for this recommendation.

The subject condenser redesign involves the following:

1. NaK shell tube radial exit ports (orifices) are increased to 0.75" diameter.
2. NaK inlet and exit tube-to-manifold joints are reinforced by increasing the tube diameters and making the manifold and tube a one-piece construction.
3. Evacuation port 1-1/2" OD - .120 wall is provided at the conical mercury inlet end.
4. Conoseal flange connection at mercury inlet is removed.
5. Mercury inlet port diameter is 4.125" ID x .063" wall.
6. Mercury exit plenum fitting is redesigned for higher strength.

Approved by:

W. M. Waters

W. M. Waters, Supervisor
Analytical Design Group
Design Engineering Section
Engineering Department

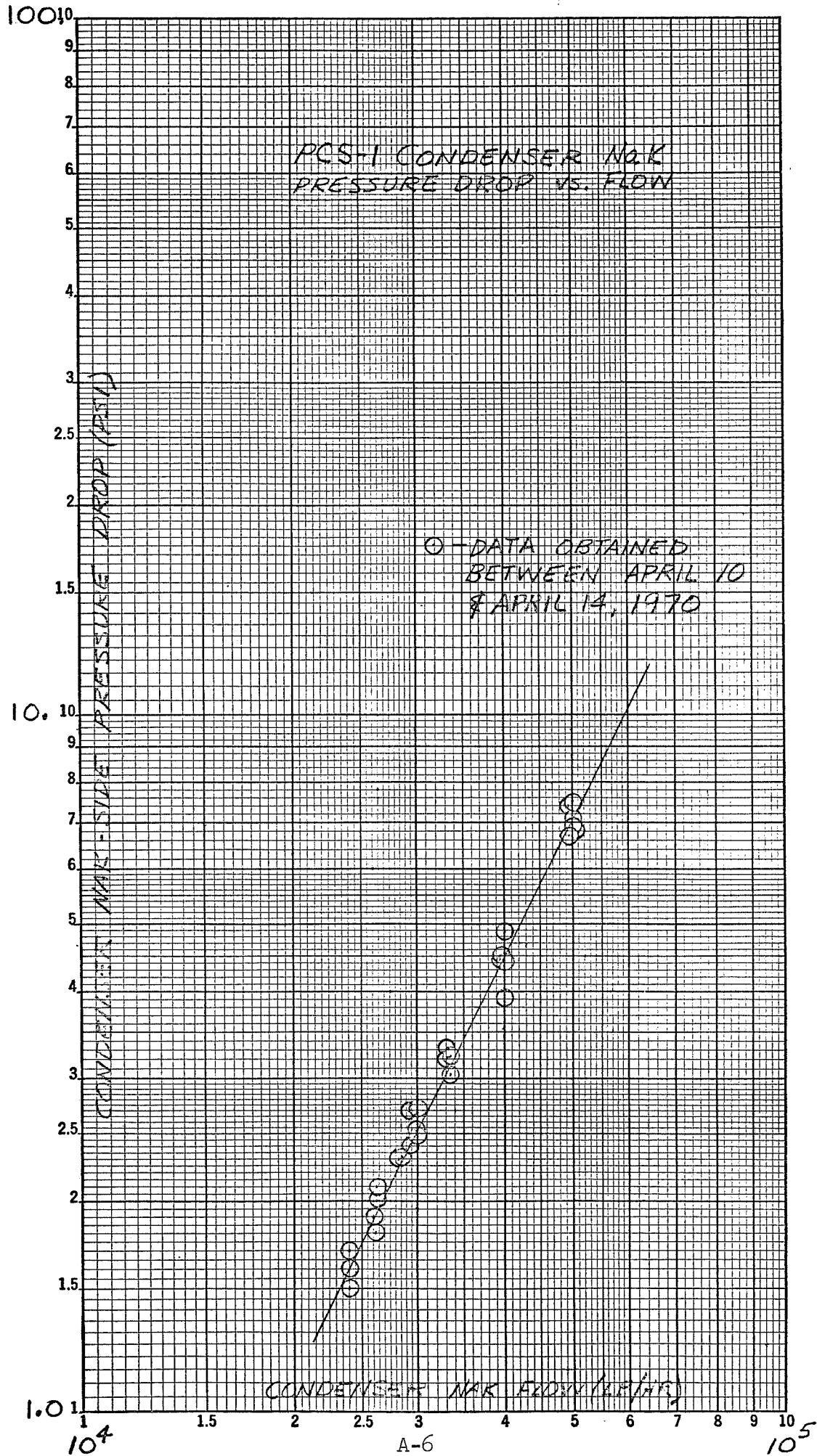
A. J. Sellers

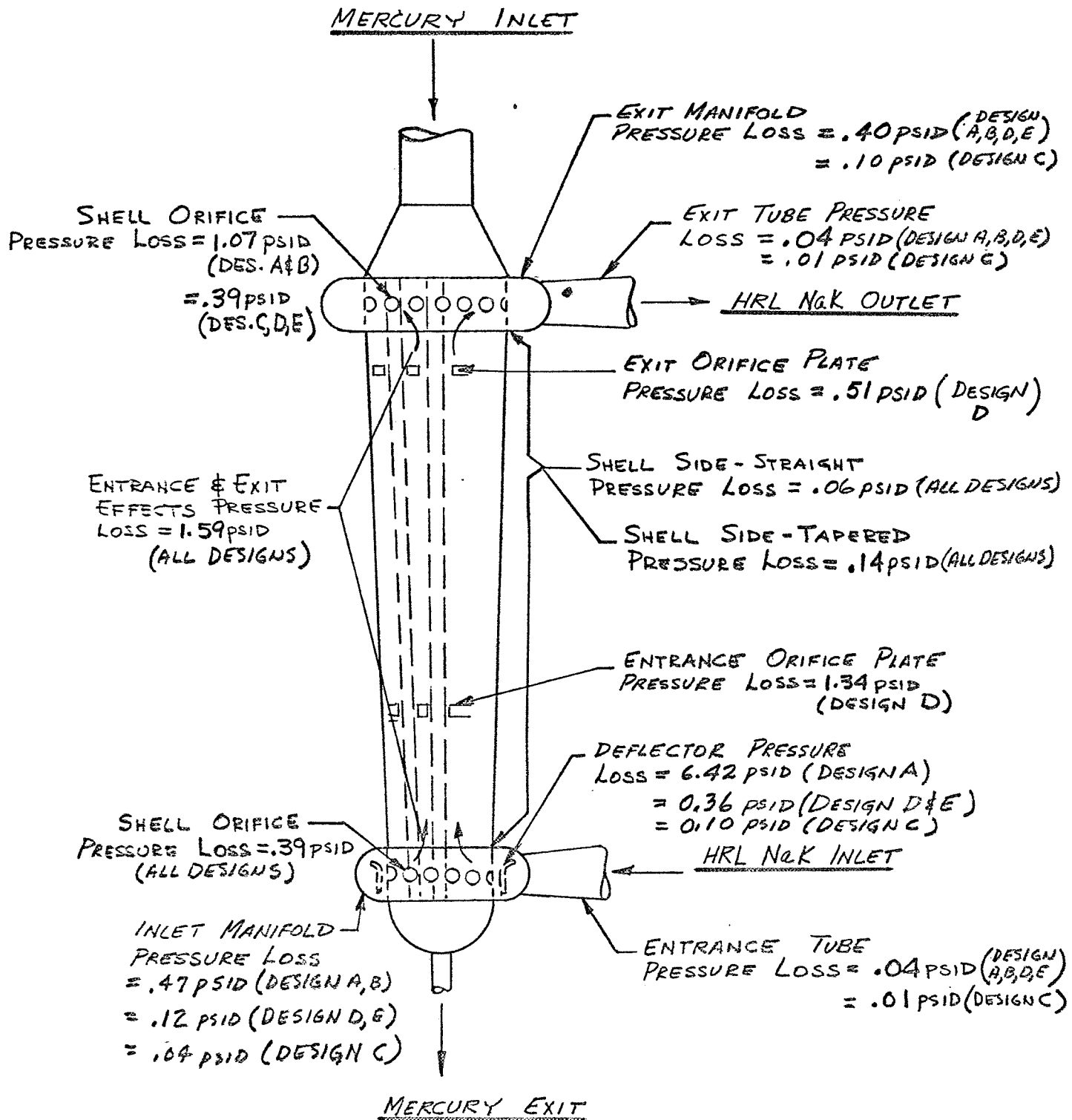
A. J. Sellers
Analytical Design Group
Design Engineering Section
Engineering Department

NAK SHELL SIDE PRESSURE DROP
AT 40,000 LB/HR NaK FLOW (DESIGNS A, B, D, and E)
AT 47,500 LB/HR NaK FLOW (DESIGN C)

	DES. A. ORIG.	DES. B PCS-1	DES. C PROPOSED	DES. D PROPOSED	DES. E PROPOSED
Entrance Tube	.04	.04	.01 ⁽⁷⁾	.04	.04
Deflector	6.42	-	.10 ⁽⁸⁾	.36 ⁽¹⁾	.36 ⁽¹⁾
Manifold Inlet	.47 ⁽⁶⁾	.47 ⁽⁶⁾	.04 ⁽⁹⁾	.12 ⁽²⁾	.12 ⁽²⁾
Shell Orifice, In	.39	.39	.39	.39	.39
Shell Side, Straight	.06	.06	.06	.06	.06
Entrance Orifice Plate	-	-	-	1.34 ⁽⁴⁾	-
Shell Side, Tapered	.14	.14	.14	.14	.14
Exit Orifice Plate	-	-	-	.51 ⁽⁴⁾	-
Shell Orifice, Out	1.07	1.07	.39 ⁽⁵⁾	.39 ⁽⁵⁾	.39 ⁽⁵⁾
Manifold, Exit	.40	.40	.10 ⁽⁹⁾	.40	.40
Exit Tube	.04	.04	.01 ⁽⁷⁾	.04	.04
Entrance and Exit Effects	1.59	1.59	1.59	1.59	1.59
Total	10.62	4.20	2.83	5.38	3.53

- Legends: (1) Deflector and baffle replaced by splitter vanes.
 (2) Manifold made eccentric to shell, baffle removed.
 (3) Original baffle removed, and Ref. (c) results.
 (4) New baffle plate used.
 (5) Shell exit orifice increased from .625" to .75" diameter.
 (6) Inlet manifold, baffle and spacers.
 (7) Increased inlet and exit tube I.D. to 2.82".
 (8) Splitter vane in 2.82" ID inlet manifold.
 (9) Increased inlet and exit manifold cross section to 1.41" radius.





SCHEMATIC — IDENTIFICATION OF PRESSURE
LOSSES THROUGH CONDENSER
AS TABULATED IN ENCLOSURE (1)

QUADRILLE WORK SHEET

AEROJET-GENERAL CORPORATION
AZUSA, CALIFORNIAPAGE 1 OF 5 PAGES
DATE 7-6-70.
WORK ORDER 1475-14-0300

HYDRAULIC ANALYSES OF PRESSURE LOSSES THRU

SUBJECT CONDENSER P/N 1268340
(DESIGN C)BY AJ. Jellum

SUMMARY - CONDENSER NAK SIDE PRESSURE DROP.

The condenser P/N 12683400 is a modified version of the PCS-1 condenser which was employed during last PCS-1 operating period (March-May 1970). To reduce the Nak side pressure drop the condenser Nak inlet and exit connections and manifolds are provided with increased flow crosssection areas. Splitter vane is provided in the inlet manifold to minimize the drag effect of the flowing Nak against the Nak shell. Also shell exit orifices are increased to a larger diameter to minimize the pressure drop. The calculated pressure drop for these modifications results in 2.85 psi. The calculations are provided in the following text.



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AZUSA, CALIFORNIA

QUADRILLE WORK SHEET

PAGE 2 OF 5 PAGESDATE 7-6-70SUBJECT CONDENSER P/N 12683400BY AJ. Sellen

WORK ORDER _____

NAK SIDE PRESSURE DROP CALCULATIONSGIVEN: $\dot{W}_N = 47500 \text{ lbm/hr}$

$$T_{in/out} = 417/518^\circ\text{F} \rightarrow \bar{T} = 467.5^\circ\text{F}$$

$$\rho = 51 \text{ lbm/ft}^3$$

$$\mu = .7 \text{ lbm/hr-ft}$$

ENTRANCE AND EXIT CONNECTION

$$D = 2.82 \text{ in.} \quad L = 4.92 \text{ in.}$$

$$G = \frac{144 \dot{W}_N}{3600 \times .785 D^2} = \frac{144 \times 47500}{3600 \times .785 \times 2.82^2} = 304.6 \text{ lbm/sec-ft}^2$$

$$U = \frac{G}{\rho} = \frac{304.6}{51} = 5.97 \text{ ft/sec.}$$

$$Re = 300 \frac{GD}{\mu} = 300 \times \frac{304.6 \times 2.82}{.7} = 368130$$

$$f = \frac{.316}{Re^{.25}} = \frac{.316}{24,63} = .013$$

$$\Delta P = f \frac{L}{D} \frac{G^2}{2g_c \rho 144} = .013 \times \frac{4.92}{2.82} \times \frac{304.6^2}{64.4 \times 51 \times 144} = .005 \approx .01 \text{ psi}$$

$$\Delta P_u = \frac{\rho \Delta H}{144} = \frac{\rho U^2}{144 \times 2g_c} = \frac{51 \times 5.97^2}{144 \times 2g_c} = .197 \text{ psi}$$

SPLITTER VANE

$$\dot{W}_N = \frac{1}{2} \times 47500 = 23750 \text{ lbm/hr per side of splitter vane.}$$

$$A_1 = \frac{1}{2} \times .785 \times 2.82^2 = 3.12 \text{ in}^2 \text{ crosssection per side}$$

$$Wp = \frac{1}{2} \pi \times 2.82 + 2.82 = 7.24 \text{ in wetted perimeter per side.}$$

$$D_e = \frac{4 \times 3.12}{7.24} = 1.72 \text{ in equivalent diameter}$$



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DATE _____

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$$G = \frac{144}{3600} \frac{W_H}{A_L} = .00913 W_H \text{ lbm/sec-ft}^2$$

$$U = \frac{G}{\rho} \text{ ft/sec.}$$

$$Re = 300 \frac{G D_L}{\mu} = \frac{300}{.7} \times 2.16 G = 926 G.$$

	W_H lbm/hr	G lbm/sec-ft ²	U ft/sec	Re
5/6	19791	180	3.53	294300
4/6	15832	144	2.83	235440
3/6	11874	108	2.12	176580
2/6	7916	72	1.41	117720
1/6	3958	36	.71	58860

From CRANE, Technical Paper No. 410 Pg. A-27 resistance of
two 90° bends is:

$$\frac{L}{D} = R_L + (n-1) \left(R_L + \frac{R_b}{2} \right)$$

where $R_L = f(r/d)$ - total resistance in one 90° bend
in L/D

$R_L = f(r/d)$ - resistance due to length
in L/D

$R_b = f(r/d)$ - bend resistance due to one
90° bend in L/D

n - total number of 90° bends in line



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DATE _____

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For $r/d = \frac{3.19}{3.82} = .84$ CRANE provides:

$$\frac{L}{D} = 28 + (2-1) \left(1 + \frac{1}{2}\right) = 29.5$$

From Stanton diagram for clean steel surface:

$$f = .019$$

Consequently

$$K_L = f \frac{L}{D} = .019 \times 29.5 = .56$$

Using 5% flow per side (conservative assumption):

$$\Delta P = .56 \times \frac{180^2}{64.451 \times 144} = .0384 \text{ psi}$$

EXIT MANIFOLD

Exit manifold flow conditions are reversed as compared to those provided for the inlet manifold. This requires additional ΔP due to fluid acceleration

$$\begin{aligned} \Delta P &= \Delta P_{in} + \frac{1}{144} \left(\frac{G_{5\%}^2}{29.69} - \frac{G_{1\%}^2}{29.69} \right) \\ &= .0384 + \frac{1}{144} \left(\frac{180^2}{64.451} - \frac{36^2}{64.451} \right) \\ &= .0384 + .0650 = .1034 \text{ psi} \end{aligned}$$

APPENDIX B

STRUCTURAL ANALYSES - MODIFIED MANIFOLD (INLET AND OUTLET)

SUMMARY OF ANALYSIS

Project	SNAP-8	Component	Condenser	Distribution:
Part	Transition Structure	Drawing No.	1268340	E. S. Chalpin
Subject	Condenser PCS-G			H. Derow
	Condenser to TAA			U. A. Pineda
	Condenser Interface Hg. Inlet End			J. R. Pope
Reference(s)				File: SS 1070-03
Engineer	J. Shen	Approved	<i>Al. Welch</i>	

OBJECTIVE:

To evaluate the structural integrity of condenser interface at the Hg inlet end.

ASSUMPTIONS:

Conditions Analyzed:

1. Complete fixity at the condenser flange and at the TAA exhaust structure.
2. Same as Cond. 1, except assumed 25% fixity at Hg inlet end.

REFERENCES (Analysis Methods):

AGC Specification 10625, the design conditions are:

1. 14 lbs/in² internal pressure.
2. Steady state operating temperature 670°F.

RESULTS AND CONCLUSIONS:

Results of the Finite Element Analysis using IBM Computer Program E11401, indicate that critical part is the low carbon steel (C-1015) area which has an allowable

$$F_{ty} = 19,500 \text{ lbs/in}^2 \text{ at } 670^\circ\text{F}$$

Condition	σ_{eff}	Estimated Low Cycle Fatigue
1	26,126 psi	170 cycles
2	23,840 psi	750 cycles

RECOMMENDATIONS AND COMMENTS:

1. Low carbon steel C-1015 part of the assembly be replaced by a higher strength metal.
2. Accept this part based on AGC Specification 10625, Para. 3.1.2.3.1 for 100 startup and shutdown sequences of operation during its operating life.
3. Conduct structural analysis of the integrated system to evaluate the effects of the mounts and supports structure.



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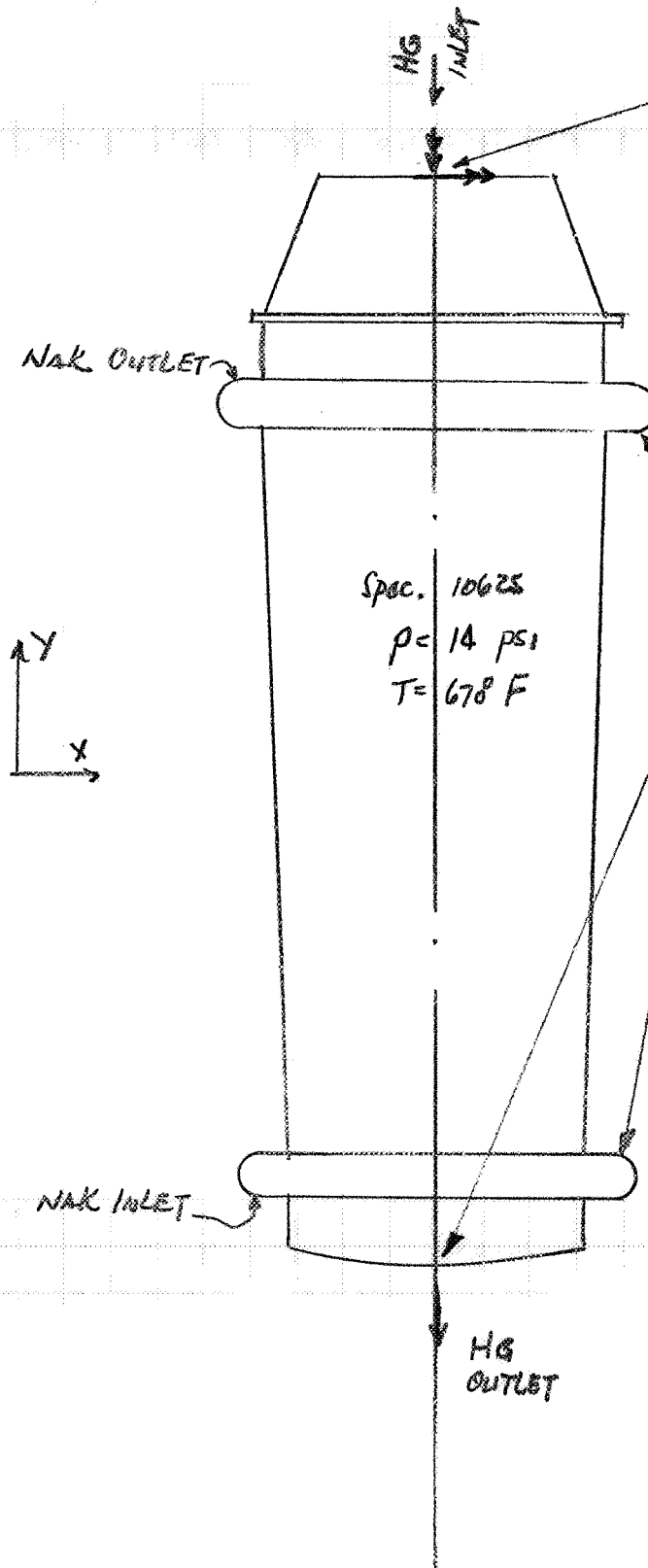
QUADRILLE WORK SHEET

PAGE 1 OF 1 PAGES

DATE 5-18-70

SUBJECT LOADS ON CONDENSER STATUS BY J. SHEN

WORK ORDER _____



DWG 097403

AXIAL FORCE = 10 LBS
RADIAL " = 50 "
MOMENT = 38 FT-LBS
TORSION = 60 FT-LBS

G/N #8 - ALL LOADS
ARE REFERENCED TO
AXIAL CENTERLINE OF
INTERFACE CONNECTION

PER D. COBINE SKETCH
DATED 3-10-70, FOR
CONDENSER #2, THE
LOADS ARE

	- FT-LBS -					
	F_x	F_y	F_z	M_x	M_y	M_z
NAK INL.	$\frac{40}{\sqrt{2}}$	100	$\frac{40}{\sqrt{2}}$	$\frac{100}{\sqrt{2}}$	100	$\frac{100}{\sqrt{2}}$
NAK OUT.	$\frac{100}{\sqrt{2}}$	100	$\frac{100}{\sqrt{2}}$	$\frac{100}{\sqrt{2}}$	100	$\frac{100}{\sqrt{2}}$
HG OUT.	$\frac{25}{\sqrt{2}}$	25	$\frac{25}{\sqrt{2}}$	$\frac{20}{\sqrt{2}}$	5	$\frac{20}{\sqrt{2}}$

NOTES

1. NAK INLET/OUTLET
LOADS ARE ORIENTED
AT 30° WITH Z-AXIS
2. Condenser supported
only at top flange

Dept. 4927

ANALYSIS NO. SA-C-126-A

DATE 5 May 1970

SUMMARY OF ANALYSIS

Project <u>SNAP-8</u>	Component <u>Condenser</u>	Distribution:
Part <u>Plenum Mercury Exit</u>	Drawing No. <u>Sketch</u>	<u>G. Lombard</u>
Subject <u>Stress Analyses Condenser Plenum (Dome)</u>		<u>E. Chalpin (Encl.)</u>
Reference(s) <u>Finite Element Comp. Program - E-11401</u>		<u>H. Derow</u>
Engineer <u>O. H. Cano</u>	Approved <u>W. A. Chaff</u>	File: SS <u>1070-03</u>

OBJECTIVE:

Perform Finite Element Analyses of Plenum Dome to determine structural integrity of two alternate configurations being proposed.

ASSUMPTIONS:

Design Criteria per Spec.: AGC 10650
AGC 70143

REFERENCES (Analysis Methods):

Program E-11401

RESULTS AND CONCLUSIONS:

Results indicate low stress levels at all points of shell. No critical zones. Maximum stress levels are:

Config. #1 - Element #176 - $\sigma_{Max.} = 2790$ psi

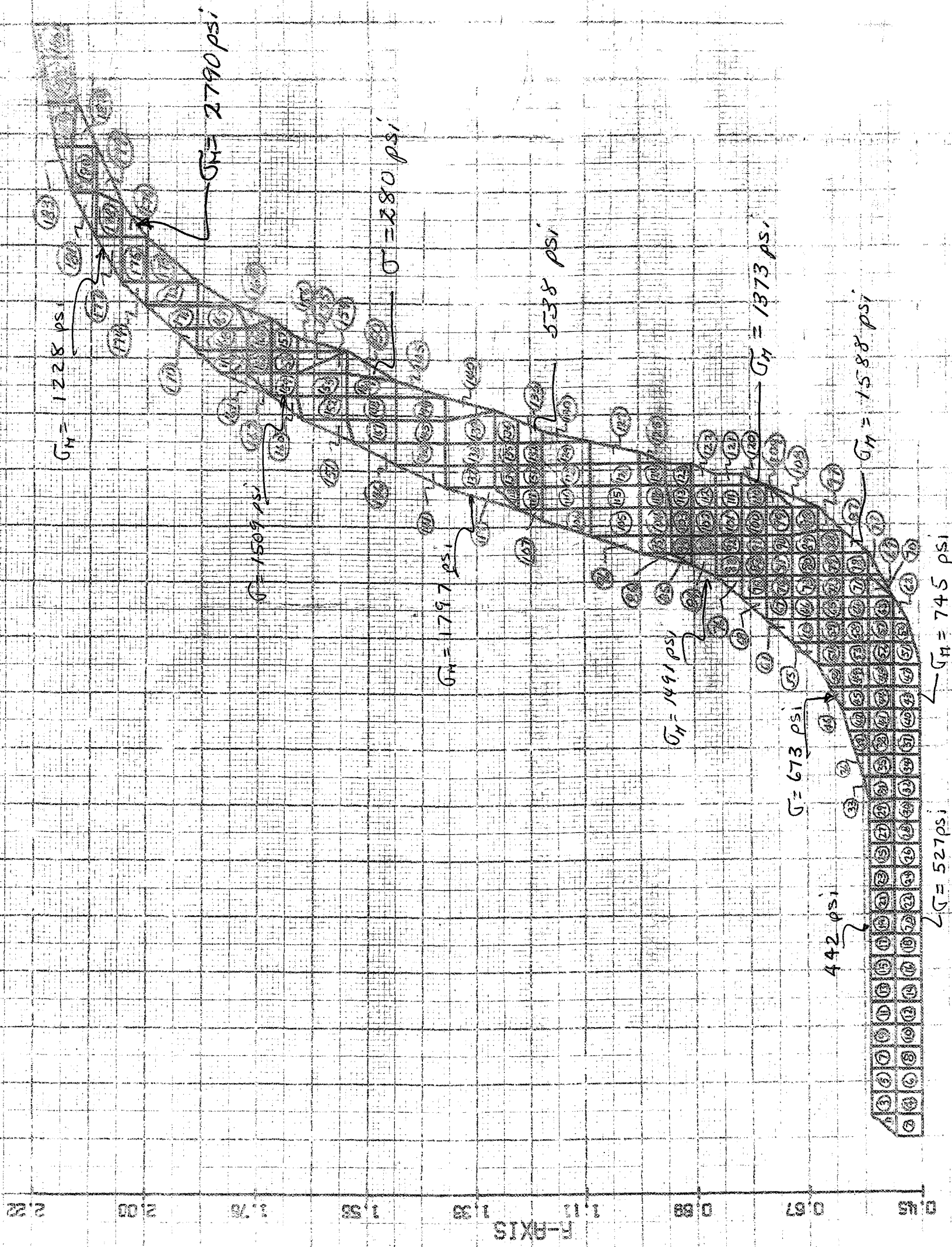
Config. #2 - Element #73 - $\sigma_{Max.} = 2472$ psi

RECOMMENDATIONS AND COMMENTS:

Accept design as shown.

PLENUM MERCURY EXIT

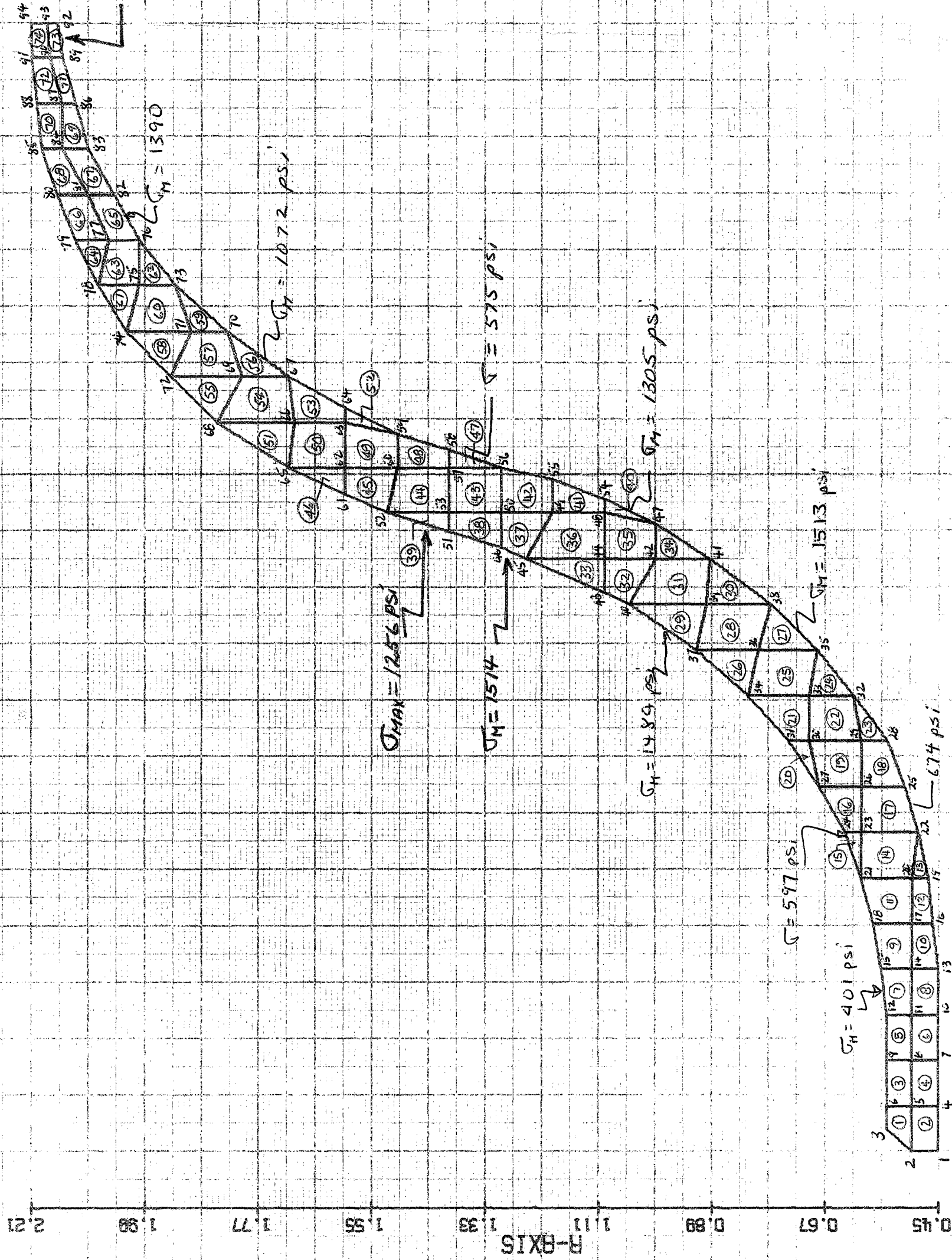
CONDENSER INLET



0069

PLENUM MERCURY EXIT

CONDENSER CONFIG 2



#6069

Dept. 4927

ANALYSIS NO. SA- C-127

DATE 8 April 1970

SUMMARY OF ANALYSIS

Project <u>SNAP-8</u>	Component <u>Condenser</u>	Distribution:
Part <u>Condenser PCS-G</u>	Drawing No. <u>1268340</u>	<u>E. Chalpin</u>
Subject <u>Structural Analyses - Modified Manifold (Inlet and Outlet)</u>		<u>G. Lombard</u>
Reference(s) <u>(1) AGC-10625 - Specification Condenser Merc.</u>		<u>File</u>
<u>(2) Dwgs: 1268340</u>	<u>1268343</u>	<u>1268346</u>
<u>1268341</u>	<u>1268344</u>	
<u>1268342</u>	<u>1268345</u>	
Engineer <u>O. H. Cano</u>	Approved <u><i>W. Delatt</i></u>	File: SS <u>1070-03</u>

OBJECTIVE: To evaluate the structural integrity of modified condenser and parts

ASSUMPTIONS: Previous analyses and tests verify structural components not covered by modifications. New analyses not required for these items.
Analyses only of new areas performed.

REFERENCES (Analysis Methods):

-

RESULTS AND CONCLUSIONS: Analyses shows ample margins in the areas investigated. Criteria calls for design to 110 psi at 910°F. Experience of project personnel indicates that this criteria is very conservative. Some minor notes made to drawings.
(Transition Dwg - Recommend inspection of commercial grade Mat'l Dwg #1268346)

RECOMMENDATIONS AND COMMENTS: Sign-off -

Interoffice Memo

To: E. S. Chalpin

Date: 13 May 1970

7974-70-C032:WW:eh

From: W. Welleff

Subject: Transition Structure Condenser to TAA

Copy to: B. Breindel, H. Derow, A. H. Kreeger, L. P. Lopez,
J. R. Pope, U. A. Pineda, J. C. Shen, file

The mercury inlet portion of the condenser was analyzed, which consist of two welded truncated sections made of 410 stainless steel and C-1015 mild steel, connecting the condenser at the one end and the turbine exhaust at the other. The Finite Element Computer Program E-11401 was used in this analysis. The design requirements for this analysis were assumed at 14 psi internal pressure and 670⁰F steady state operation temperature. Three computer runs were performed using the same geometrical configuration by varying the end conditions. A final design for the mountings and support structure of the condenser and the TAA as integrated in the PCS is not available at the present time, and hence the analysis does not include the flexibility of this configuration. Initially a very conservative assumption was made that both ends of this section are fixed. The objective of the assumption for the first computer run was to obtain the stress levels in the section and if acceptable, and below the corresponding yield strength of the materials, no additional analysis will be made. If the stress levels, however, are high, additional end conditions will be investigated. The second computer run was made under the assumption that 75% of the pipe deformation caused by the thermal expansion be resisted by the TAA structure. A third computer run was made in which the resistance of the TAA end on the pipe was 25%. Review of the computer output, particularly of the effective stresses and strains, indicated that various areas in the section where carbon steel material is used (the section with the smallest diameter at the TAA end of the junction) experiences stress levels above the yield strength of the material at this temperature: 23,840 psi vs. 19,500 psi. The over-yield stress condition was found for all three assumptions.

If a requirement is imposed on the connecting parts to have the stress level below the yield strength of the material and the assumed configuration is retained, this design of the material is not adequate. There are two possible steps available for improvement:

(a) Increase the wall thickness of the pipe, or (b) replace the mild steel material with material having higher strength, equal ductility and compatibility with the mercury flow to resist corrosion. The Materials Group was informed of the need for such a material. Meanwhile discussion was held on this subject. The materials found to satisfy the above-mentioned conditions require post-weld heat treatment, which appears to be impractical.

If plastic deformations are allowed, and low cycle fatigue life (which we are presently calculating) is acceptable, and within the specification requirements, the use of mild steel for this design will be considered acceptable. It is suggested, however, that when final integration of this component into the PCS is made, the effects of mounts and support structure on the structural integrity of the condenser and the TAA be re-evaluated and an integrated system structural analysis be made.



W. Welleff, Supervisor
Structural Analysis
Engineering Department

APPENDIX C

DESIGN REVIEW CHECK LIST

POWER SYSTEMS DIVISION

DESIGN REVIEW CHECK LIST

SUBJECT UNDER REVIEW (Name, Part No.): Condenser, PCS-G

P/N 1268340

This Design Review Check List is an integral part of the design review documentation package, required by Power Systems Division Procedure I-A6c, "Design Review Plan."

The items specified on the Design Review Check List provide the basis for a comprehensive review. However, they are not necessarily all inclusive. The design engineer shall be guided by the basic requirement for a thorough and detailed evaluation of a design, as stated under Section 3, "SCOPE," of this procedure, and shall expand the list where necessary.

Check List entries shown herein provide current information on the design under review and are intended to reflect the basis for and readiness of the design for entry into its next evolutionary phase.

REVIEWED BY:

PRESENTED BY:

W. Aleff 7/8/70
Stress Date

ES Chalpus 5/14/70
Design Engineer Date

[Signature] 7/9/70
Reliability Date
for Bill Arnstader

DESIGN APPROVAL:
[Signature] 7/15/70
W. Aleff 7/16/70
Department Manager Date

Estanovich 7/9/70
Quality Assurance Date

PSD DESIGN REVIEW CHECK LIST

Page 2 of 12

SUBJECT NAME: <u>CONDENSER, PCS-G</u>		YES	NO	N/A	REFERENCE DOCUMENTS
P/N <u>1268340</u>					
DESIGN ENGINEER: <u>E. S. CHALPIN</u> DATE <u>5/14/70</u>					
<u>Item No.</u>	<u>General</u>				
1.	Is the basic design objective clearly defined?	X			
2.	Are the performance parameters and output requirements definitive and not subject to misinterpretation?	X			
3.	Are performance tolerances delineated?	X			
4.	Are failure criteria delineated?	X			
5.	Were alternate designs considered in selecting the present design?	X			
6.	Were redundancy needs analyzed and results used in the design?	X			
7.	Were simplification techniques applied?	X			
8.	Was a failure modes and effects analysis made?			X	
9.	Have adequate safety margins been incorporated for each important failure mode?			X	
10.	If item has a limited life, is it so designated?			X	
11.	Have maintainability requirements been considered?	X			
12.	Have previous test data and failure reports been reviewed and results used in the design?	X			
13.	Is the method of component identification specified? (The method of marking and location must be compatible with use-environment.)	X			
14.	If documentation of inspection findings is required, are the characteristics to be observed and their frequency and method of inspection defined?	X			
15.	If operational or functional acceptance testing is required, are the parameters, mode of testing, and equipment defined?	X			

PSD DESIGN REVIEW CHECK LIST

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SUBJECT NAME: _____		YES	NO	N/A	REFERENCE DOCUMENT
_____ P/N _____					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>General</u>				
16.	Are required special inspection equipments, tools, and gages defined?			X	
17.	Has a procurement plan for this material been established?	X			
18.	Have qualified and preferred parts been used where applicable?	X			
19.	Is the design notebook and file up to date and ready for audit?	X			
20.	Have provisions been made for preservation, packaging, handling, storage, and shipping?	X			
21.	Were trade-off studies made and utilized in selecting the design?	X			
22.	Does the design minimize the probability of human errors during installation, checkout, and operation, such as reversed connections, parts installed backward, no lubrication during startup, etc.?	X			
23.	Does the design make appropriate use of "fail-safe" devices or techniques?			X	
24.	Does the design comply with all applicable specifications?	X			
25.	Were the action items from the previous Design Review carried out?			X	
26.	Is the design compatible with the requirements of the end item?	X			

PSD DESIGN REVIEW CHECK LIST

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SUBJECT NAME: _____		YES	NO	N/A	REFERENCE DOCUMENTS
P/N _____					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Mechanical</u>				
1.	Has a stress analysis been made?	X			See Appendix "B"
2.	Have areas of high stress concentrations such as sharp corners, radii, and re-entrant angles been eliminated?	X			See Appendix "B"
3.	Has a thermal analysis been made?	X			See Appendix "B"
4.	Is thermal expansion likely to have adverse effects on dimensions and tolerances?		X		
5.	Has a tolerance analysis been made to verify proper fitting of parts under extremes of tolerance buildup?	X			Dwg. 1268340-1
6.	Did the tolerance analysis consider operating loads and temperatures?	X			Dwg. 1268340-1
7.	Were static, dynamic and magnetic balances and their tolerances considered?			X	
8.	Has a wearout analysis for all rubbing and rolling parts been made?			X	
9.	Have the installation torques and tolerances of all fasteners and their stress effects been evaluated?			X	
10.	Is the inspectability of the component assured? (Are the true positioning and contour requirements designed to enable inspection of part?)	X			Dwg. 1268340-1
11.	Has the mechanical compatibility with the complete system been verified?	X			Dwg. 1268340-1
12.	Does mechanical design reflect simplest method, from manufacturing view, to meet needed parameters?	X			Dwg. 1268340-1
13.	Were environmental effects (including those of nuclear radiation) considered along with safety requirements during design?	X			Dwg. 1268340-1

PSD DESIGN REVIEW CHECK LIST

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SUBJECT NAME: _____		YES	NO	N/A	REFERENCE DOCUMENTS
_____ P/N _____					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Electrical</u>				
1.	Are the design essentials adequately defined, including performance, longevity, and repetitive operation requirements?			X	
2.	Is the design compatible with the life cycle conditions to which the equipment will be exposed?			X	
3.	Have the stability and drift requirements and the effects of environments on these characteristics been considered?			X	
4.	Was a simplification study made and applied?			X	
5.	Is redundancy employed where beneficial; are possible side effects taken into consideration?			X	
6.	Were reliability characteristics considered and documented in parts and materials selection?			X	
7.	Are the part tolerances consistent with design requirements?			X	
8.	Was adequate derating employed, including sufficient margin for transients and other excessive stresses?			X	
9.	Can the parts operation result in undesirable conditions of temperature, voltage, current, or RFI for other parts or assemblies? If so, was this info used in the design?			X	
10.	Are the dielectric breakdown and insulation resistance properties adequate for the most severe environments?			X	
11.	Is hermetic sealing employed where beneficial?			X	
12.	Are type of connections employed reliable?			X	

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4925:66:107

PSD DESIGN REVIEW CHECK LIST

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SUBJECT NAME: _____		YES	NO	N/A	REFERENCE DOCUMENTS
_____ P/N _____					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Electrical</u>				
13.	Have all applicable specifications been called out?			X	
14.	Have the preferred parts lists (JPL Specification No. 20061C and CSFC-PPL-1) been used?			X	
15.	Has expected hot spot temperatures been determined and considered?			X	
16.	Has effect of component operation on primary power wave form been considered?			X	
17.	Has nuclear radiation environment effects been considered?			X	
NOTE: The following electrical characteristics should be considered: inductance, capacitance, resistance, sensitivity, leakage, insulation, shielding; distortion, gain, phase, attenuation; slope, harmonics, eddy currents; time, spikes, peaks, contact resistance, contact rating, torque, wire size					

PSD DESIGN REVIEW CHECK LIST

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SUBJECT NAME: _____		YES	NO	N/A	REFERENCE DOCUMENTS
_____ P/N _____					
DESIGN ENGINEER: _____ DATE _____					
Item No.	Materials				
1.	Are all materials adequately identified by MIL, Fed, AGC, or comparable specifications?*	X			Dwg. 1268340-1
2.	Is the source of supply specified for qualified/preferred materials?	X			Dwg. 1268340-1
3.	Are the strength characteristics of the materials including tensile, compressive, shear, yield, bending, creep, and fatigue satisfactory for intended use?	X			See Appendix "B"
4.	Is each material employed within limits defined by its endurance limit curve?	X			See Appendix "B"
5.	Have adequate safety margins been used to provide protection from failure due to corrosion, vibration, shock, fatigue, and other stress factors?	X			AGC 10625
6.	Are the hardness, ductility, and other characteristics suitable for both the manufacturing processes and application?	X			AGC 10625
7.	Will the material characteristics be significantly changed by exposure to environments, particularly radiation?		X		
8.	Are the special inspection and test processes compatible with the parts and materials?	X			AGC 10625
9.	Are the thermal expansion characteristics suitable for the intended use?	X			AGC 10625
10.	Will the materials be compatible with mating parts, fluids, and gases and not act as catalytic agents?	X			AGC 10625
11.	Does each material have suitable electrical and magnetic properties for its application?			X	

* The order of precedence for specifications must meet MIL-STD-143 requirements.

PSD DESIGN REVIEW CHECK LIST

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SUBJECT NAME: _____		YES	NO	N/A	REFERENCE DOCUMENTS
_____ P/N _____					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Materials</u>				
12.	Have adequate metallurgical controls been imposed to assure that each material conforms to its specification?	X			AGC 10625
13.	Are all tolerances specified and are they compatible with the materials and required manufacturing methods?	X			AGC 10625
14.	If mechanical, metallurgical, and/or chemical testing is required, are the necessary samples, coupons, or test bars defined, and test methods established?			X	

PSD DESIGN REVIEW CHECK LIST

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SUBJECT NAME: _____		YES	NO	N/A	REFERENCE DOCUMENTS
_____ P/N _____					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Manufacturing Processes</u>				
1.	Are the specified fabrication methods suited to the design and materials?	X			AGC 10625
2.	Are the process capabilities consistent with component requirements?	X			AGC 10625
3.	Is heat treating, stress relief, nitriting, flame hardening, or other special process required?	X			Dwg. 1268340-1
4.	Will processing and assembly affect the dimensions?			X	
5.	Are process specifications and tolerances designated?	X			Dwg. 1268340-1
6.	Are requirements after processing and assembly specified?	X			Dwg. 1268340-1
7.	Have joining methods (welding, brazing, soldering, fastening) been selected to minimize effect on tolerances and part variations?	X			Dwg. 1268340-1
8.	Are special inspection and test processes such as radiograph, helium leak test, and penetrant dye check required?	X			Dwg. 1268340-1
9.	If so, are acceptance criteria specified?	X			Dwg. 1268340-1
10.	Has the most suitable cleaning method been specified?	X			Dwg. 1268340-1
11.	Is a protective coating required?	X			Dwg. 1268340-1
12.	If so, will protective coating affect mating parts?		X		
13.	Are special assembly requirements such as sligment, torque, lock wiring, static balancing, or dynamic balancing defined and documented?			X	
14.	Is there an assembly instruction or specification?	X			AGC 10448

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4925:66:107

SUBJECT NAME: _____		YES	NO	N/A	REFERENCE DOCUMENTS
_____ P/N _____					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Manufacturing Processes</u>				
15.	Are the clean room environmental characteristics defined (such as maximum particle size, count, temperature, flow rate, etc.)?	X			AGC 10625
16.	Are there special packaging, handling, or storage requirements?	X			Dwg. 1268340-1
17.	Are the special process operator and equipment qualification requirements specified?	X			AGC 10625
18.	Are the surface finish, waviness, and lay adequately defined?			X	
19.	Are workmanship acceptance standards defined?	X			AGC 10625
20.	Are the applicable workmanship specifications referenced?	X			AGC 10625
21.	Is a Build-up and Assembly Log required?	X			AGC 10625

PSD DESIGN REVIEW CHECK LIST

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SUBJECT NAME: _____		YES	NO	N/A	REFERENCE DOCUMENTS
_____ P/N _____					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Environment</u>				
1.	Have the environmental exposures, levels, and durations been fully determined?	X			AGC 10625
2.	Have the environmental effects on component performance, longevity, and reliability been evaluated?	X			AGC 10625
3.	Does operation of the component generate environments which are detrimental to the component or to other assemblies or subsystems?			X	
4.	Can the component withstand external and self-generated environments without employment of isolation devices?	X			See Appendix "B"
5.	Is adequate protection from environments specified in detail where required?	X			AGC 10625
6.	Were the relationships between environments and modes of failure considered in the failure mode and effects analysis?			X	
<p>NOTE: The following environments should be considered: heat, cold, thermal shock, high pressure, vacuum, pressure shock, humidity; vibration, acoustic noise, acceleration, shock, RFI-radiated, RFI- conducted, RFI-susceptibility; explosive atmosphere, solar radiation, nuclear radiation, salt atmosphere, fungus, meteoroids, zero-gravity, sand, dust, wind.</p>					

PSD DESIGN REVIEW CHECK LIST

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SUBJECT NAME: _____		YES	NO	N/A	REFERENCE DOCUMENTS
P/N _____					
DESIGN ENGINEER: _____ DATE _____					
<u>Item No.</u>	<u>Instrumentation</u>				
1.	Have accuracy and precision requirements been specified for performance parameters?	X			AGC 10625
2.	Have provisions been made for instrumentation to meet these requirements?	X			AGC 10625
3.	Have sensor installation requirements, including hermetic sealing and removal or replacement, been considered?	X			AGC 10625
4.	Will the insertion of sensors affect the operation of the component?		X		
5.	Is adequate instrumentation available for anticipated operating conditions?	X			AGC 10625
6.	Is an instrumentation development program necessary?		X		
7.	Are written calibration instructions available for the calibration of data gathering equipment?	X			AGC 10625
8.	Has an adequate and reliable instrumentation wiring system been defined?			X	